

TITLE OF THE INVENTION

MRAM HAVING MEMORY CELL ARRAY IN WHICH CROSS-POINT  
MEMORY CELLS ARE ARRANGED BY HIERARCHICAL BIT LINE  
SCHEME AND DATA READ METHOD THEREOF

5 CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the  
benefit of priority from the prior Japanese Patent  
Application No. 2003-144792, filed May 22, 2003, the  
entire contents of which are incorporated herein by  
10 reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a magnetic random  
access memory (MRAM) which stores binary information  
15 using the magnetoresistive effect, and a data read  
method thereof and, more particularly, to potential  
control of main/sub bit lines and word lines in the  
read mode of a memory cell array in which cross-point  
memory cells are arranged by a divided bit line  
20 structure (hierarchical bit line scheme).

2. Description of the Related Art

MRAMs are devices which perform memory operation  
by storing binary information using the  
magnetoresistive effect. They are regarded as one of  
25 candidates for universal storage devices that can  
realize all the nonvolatility, high integration degree,  
high reliability, low power consumption, and high

operation speed and have been developed in various companies.

Two effects, i.e., the GMR (Giant MagnetoResistive) effect and TMR (Tunneling MagnetoResistive) effects are mainly known as magneto-resistive effects. An element (GMR element) using the GMR effect stores information by using a phenomenon that the resistance of a conductor sandwiched between two ferromagnetic layers changes depending on the direction of spin of the ferromagnetic layers on the upper and lower sides. In the GMR element, however, the MR ratio that indicates the ratio of a change in magnetoresistance is as low as 10%. For this reason, the read signal of stored information is small. How to ensure the read margin presents a significant challenge in implementing MRAMs. The practical utility is believed to be still insufficient at present.

As a typical element which uses the TMR effect, an MTJ (Magnetic Tunnel Junction) element which uses a change in magnetoresistance due to a spin polarization tunneling effect is known. The MTJ element has a multilayered structure in which an insulating film (tunnel insulating film) is sandwiched between two metal layers formed from ferromagnetic layers. In the MTJ element, when the directions of spin of the upper and lower

ferromagnetic layers are parallel, the tunnel probability between the two ferromagnetic layers through the tunnel insulating film is maximum. As a result, the resistance value is minimized.

5      Conversely, when the directions of spin are anti-parallel, the tunnel probability is minimum. Accordingly the resistance is maximized. To realize the two spin states, normally, one of the ferromagnetic layers (magnetic films) has a fixed magnetization direction and is set not to receive the effect of  
10      external magnetization. Generally, the ferromagnetic layer with the fixed magnetization direction is called a pinned layer. The magnetization direction of the other ferromagnetic layer (magnetic film) can be  
15      programmed to be parallel or anti-parallel to the pinned layer in accordance with the direction of an applied magnetic field. This ferromagnetic layer is generally called a free layer and has the function of storing information. Currently, MTJ elements with  
20      an MR ratio of more than 50% are available. The MTJ elements are becoming the mainstream of MRAM development.

         In the write mode of an MRAM using MTJ elements, to reverse the magnetization direction of the free  
25      layer, currents having predetermined magnitudes or more are supplied to bit lines and word lines, which pass through memory cells while crossing perpendicularly.

In accordance with the magnitude of a thus generated synthesized magnetic field, the magnetization direction of the free layer is controlled, thereby writing information.

5           Conversely, in a read mode, a voltage is applied between the two magnetic films of an MTJ element corresponding to a selected bit line, and a resistance is read from a current that flows through the MTJ element. Alternatively, a constant current is supplied  
10          to a selected MTJ element, and a voltage generated between two magnetic films is detected.

          An example of an MRAM using MTJ elements is reported in, e.g., ISSCC2000 Digest of Technical Paper p. 128 "A 10ns Read and Write Non-Volatile Memory Array  
15          using a Magnetic Tunnel Junction and FET Switch in each Cell". However, the MRAM described in this reference is designed to store 1-bit data using two MOS transistors and two MTJ elements. Hence, it is difficult to increase the capacity or the degree of  
20          integration. If the capacity or the degree of integration is increased, the access speed may decrease due to an increase in parasitic capacitance or parasitic resistance.

          To increase the capacity or the degree of  
25          integration, a structure which stores 1-bit data using one selection element (MOS transistor or diode) and one MTJ element has been proposed. In addition,

a structure which is called a cross-point structure has also been proposed, which requires no cell selection element for a memory cell, i.e., stores 1-bit data using one MTJ element. When the cross-point memory cell is used, the read speed may decrease, or the read margin may become small. Further improvements are demanded.

#### BRIEF SUMMARY OF THE INVENTION

According to an aspect of the present invention, there is provided a magnetic random access memory comprising a plurality of cell units each of which comprises cross-point memory cells that exhibit a magnetoresistive effect, word lines each of which is connected to one terminal of a corresponding one of the memory cells in each cell unit, sub bit lines each of which is commonly connected to the other terminal of each of the plurality of memory cells as a predetermined unit in each cell unit, main bit lines which are commonly connected to the plurality of sub bit lines through switch circuits, respectively, and form a hierarchical bit line structure together with the sub bit lines, a column select circuit configured to select the main bit line and connect the main bit line to a sense amplifier, and a row select circuit configured to select the word line for each cell unit by controlling the switch circuits, and in read operation, set, in a floating state, the word lines

except the selected word line with a selected memory cell connected, to which unselected memory cells connected to the sub bit line to which the selected memory cell is connected are connected, and set the word lines connected to the memory cells in the cell unit which does not include the selected memory cell to the same potential as that of the main bit line.

According to another aspect of the present invention, there is provided a magnetic random access memory comprising a memory cell array of a hierarchical bit line scheme in which cross-point memory cells that exhibit a magnetoresistive effect are laid out in a matrix, and a read bit line to be used in a data read mode is constituted by a main bit line and a sub bit line, and word line potential setting means for, in read operation, setting, in a floating state, word lines to which unselected memory cells connected to the sub bit line to which the selected memory cell is connected are connected, and setting word lines except the word lines, which are connected to sub bit lines which do not include the selected memory cell to a potential substantially equal to the main bit line.

According to still another aspect of the present invention, there is provided a magnetic random access memory comprising a memory cell array of a hierarchical bit line scheme in which cross-point memory cells that exhibit a magnetoresistive effect are laid out in

a matrix, and a read bit line to be used in a data read mode is constituted by a main bit line and a sub bit line, connection means for selectively connecting a word line to select the memory cell to one of first  
5 and second potential supply sources which are different from each other, and control means for controlling the connection means to set the word line in an electrical floating state.

According to still another aspect of the present  
10 invention, there is provided a method of reading data from a magnetic random access memory including a memory cell array of a hierarchical bit line scheme in which cross-point memory cells that exhibit a magnetoresistive effect are laid out in a matrix, and  
15 a read bit line to be used in a data read mode is constituted by a main bit line and a sub bit line, comprising setting a word line connected to a memory cell to be selected to a significant level and setting word lines in a floating state, the word lines being  
20 connected to unselected memory cells connected to the sub bit line to which the memory cell to be selected is connected, and setting word lines except the word lines, which are connected to the sub bit lines which do not include the selected memory cell, to a potential  
25 substantially equal to the main bit line.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a block diagram showing the main part

and, more particularly, the core portion of the read system of a magnetic random access memory (MRAM) according to the first embodiment of the present invention;

5           FIG. 2 is a timing chart of the read operation of the MRAM shown in FIG. 1;

          FIG. 3 is a block diagram showing the main part and, more particularly, the core portion of the read system of a magnetic random access memory (MRAM) according to the second embodiment of the present  
10           invention;

          FIG. 4 is a timing chart of the read operation of the MRAM shown in FIG. 3;

          FIG. 5 is a block diagram showing the main part and, more particularly, the core portion of the read system of a magnetic random access memory (MRAM) according to the third embodiment of the present  
15           invention;

          FIG. 6 is a timing chart of the read operation of the MRAM shown in FIG. 5;  
20

          FIG. 7 is a block diagram showing the DSL (Digital Subscriber Line) data path portion of a DSL modem so as to explain Application Example 1 of the MRAMs according to the first to third embodiments of the present  
25           invention;

          FIG. 8 is a block diagram showing a cellular telephone terminal so as to explain Application



Example 2 of the MRAMs according to the first to third embodiments of the present invention;

FIG. 9 is a plan view showing an example in which an MRAM is applied to a card (MRAM card) such as  
5 a smart medium which stores media contents so as to explain Application Example 3 of the MRAMs according to the first to third embodiments of the present invention;

FIG. 10 is a plan view showing a transfer  
10 apparatus to transfer data to an MRAM card;

FIG. 11 is a sectional view showing the transfer apparatus to transfer data to an MRAM card;

FIG. 12 is a sectional view showing a fitting type transfer apparatus to transfer data to an MRAM card;  
15 and

FIG. 13 is a sectional view showing a slide type transfer apparatus to transfer data to an MRAM card.

#### DETAILED DESCRIPTION OF THE INVENTION

##### [First Embodiment]

20 FIG. 1 is a block diagram showing the main part of a magnetic random access memory (MRAM) according to the first embodiment of the present invention. The present invention is related to a read operation. For the sake of simplicity, FIG. 1 shows the core portion of the  
25 read system and does not illustrate the core portion of the write system. Memory cells MC11 to MC48 each constructed by an MTJ element are arranged in

a plurality of (two) memory cell blocks (cell units).  
One terminal of each to memory cells MC11 to MC14, MC21  
to MC24, MC31 to MC34, and MC41 to MC44 in the first  
memory cell block is connected by fours to  
5 a corresponding one of sub bit lines SBL1, SBL3, SBL5,  
and SBL7 serving as common nodes. One terminal of each  
to memory cells MC15 to MC18, MC25 to MC28, MC35 to  
MC38, and MC45 to MC48 in the second memory cell block  
is connected by fours to a corresponding one of sub bit  
10 lines SBL2, SBL4, SBL6, and SBL8 serving as common  
nodes. The sub bit lines SBL1 to SBL8 are respectively  
connected, for each column, to main bit lines MBL1 to  
MBL4 through the current paths of select MOS  
transistors Q1 to Q8 each functioning as a select  
15 switch (switch circuit). That is, as a cell unit  
selection signal, a high-level gate signal is supplied  
to one of the select MOS transistors Q1 to Q8 of the  
sub bit lines SBL1 to SBL8 including a selected cell.  
In other words, when a select line SS1 or SS2 is  
20 changed to a high potential, a specific one of the sub  
bit lines SBL1 to SBL8 can be selectively connected to  
a corresponding one of the main bit lines MBL1 to MBL4  
for each cell unit.

A column select circuit is connected to the main  
25 bit lines MBL1 to MBL4. The column select circuit  
includes bias circuits 31-1 to 31-4, MOS transistors  
Q11 to Q14 serving as column select gates, column

select lines CSL1 to CSL4, and a column decoder & column select line (CSL) driver 33.

More specifically, one end of each of the main bit lines MBL1 to MBL4 is connected to a corresponding one of the bias circuits 31-1 to 31-4. A predetermined bias voltage is applied to all the main bit lines MBL1 to MBL4. In addition, one end of each of the main bit lines MBL1 to MBL4 is selectively connected to a sense amplifier 32 through a corresponding one of the MOS transistors Q11 to Q14 such that data stored in the memory cells MC11 to MC18, MC21 to MC28, MC31 to MC38, or MC41 to MC48 are detected and amplified and read out to another circuit outside or inside the chip. The gate of each of the MOS transistors Q11 to Q14 is connected to a corresponding one of the column select lines CSL1 to CSL4. The output signals from the column decoder & column select line driver 33 are input to the column select lines CSL1 to CSL4.

On the other hand, the other terminal of each of the cross-point memory cells MC11 to MC18, MC21 to MC28, MC31 to MC38, and MC41 to MC48 is connected to an interconnection layer that changes for each row. In the read mode, the interconnection layers function as read word lines RWL (RWL1 to RWL8). Row select circuits are arranged at two ends of each of the read word lines RWL1 to RWL8. The row select circuits include MOS transistors Q31 to Q38, a bias circuit 36,

first row decoders & read word line drivers 35-1 and 35-2, MOS transistors Q21 to Q28, and second row decoders & read word line drivers 34-1 and 34-2.

5 More specifically, one end of each of the current paths of the MOS transistors Q31 to Q38 is connected to one end of a corresponding one of the read word lines RWL1 to RWL8. The other end of each of the current paths of the MOS transistors Q31 to Q38 is connected to the output terminal of the bias circuit 36. The MOS  
10 transistors Q31 to Q38 are driven for each cell unit by word line potential setting signals RWLSET1 and RWLSET2 output from the first row decoders & read word line drivers 35-1 and 35-2. The read word lines RWL1 to RWL4 or RWL5 to RWL8 are selectively set to the bias  
15 voltage output from the bias circuit 36. The bias circuit 36 generates a bias voltage almost equal to that of the bias circuits 31-1 to 31-4 for the bit lines.

One end of each of the current paths of the MOS  
20 transistors Q21 to Q28 is connected to the other end of a corresponding one of the read word lines RWL1 to RWL8. The other end of each of the current paths of the MOS transistors Q21 to Q28 is connected to a Vss power supply (ground potential) as a reference  
25 potential. The MOS transistors Q21 to Q28 are individually driven by word line drive signals RWLACT1 to RWLACT8 output from the second row decoders & read

word line drivers 34-1 and 34-2. The read word lines RWL1 to RWL8 (interconnection layers) are selectively set to a low voltage level (e.g., Vss level).

5       The second row decoders & read word line drivers 34-1 and 34-2 and the first row decoders & read word line drivers 35-1 and 35-2 use different word line potential control methods depending on whether the word lines RWL1 to RWL8 can be controlled individually or for each cell unit (or for each sub bit line).

10       For example, assume that the memory cell MC22 indicated by a broken line is selected in the data read mode. The gate input signal (select line SS1) of the select MOS transistor Q3 arranged between the sub bit line SBL3 and the main bit line MBL2, which correspond  
15       to the memory cell MC22, is changed to a high potential to turn on the select MOS transistor Q3 and connect the main bit line MBL2 to the sub bit line SBL3. In addition, only the word line drive signal RWLACT2 corresponding to the selected memory cell MC22 is  
20       changed to a high potential by the second row decoder & read word line driver 34-1. The word line potential setting signal RWLSET1 is changed to a low level by the first row decoder & read word line driver 35-1.

25       With this operation, a current path is formed from the main bit line MBL2 to the read word line RWL2 through the sub bit line SBL3. Subsequently, an externally input column address signal is decoded by

a column decoder in the column decoder & CSL driver 33.  
The column select signal CSL2 is changed to a high  
potential by the CSL driver to turn on the MOS  
transistor Q12 and connect the main bit line MBL2 to  
5 the sense amplifier 32. At this time, the bias circuit  
(bit line bias circuit) 31-2 connected to the main bit  
line MBL2 is set in an inactive state by the column  
select signal CSL2.

An equipotential (a potential almost equal) to  
10 the bit line bias circuit 31-2 is applied from the  
sense amplifier 32 to the selected main bit line MBL2.  
A current that flows to the selected cell MC22 is  
detected and amplified to read out the stored  
information.

15 At this time, the word lines RWL1, RWL3, and RWL4  
connected to the unselected cells (MC21, MC23, and  
MC24) connected to the sub bit line SBL3 including the  
selected cell MC22 are controlled to a floating state  
by the row decoders & read word line drivers 35-1  
20 and 34-1. On the other hand, the word lines RWL5 to  
RWL8 connected to the unselected cells MC15 to MC18,  
MC25 to MC28, MC35 to MC38, and MC45 to MC48 connected  
to the sub bit lines SBL2, SBL4, SBL6, and SBL8, which  
do not include the selected cell MC22, are set to the  
25 bias voltage output from the bias circuit 36, i.e.,  
a bias voltage almost equal to the main bit lines MBL1  
to MBL4 because the MOS transistors Q35 to Q38 are set

in an ON state and the MOS transistors Q25 to Q28 are set in an OFF state by the row decoders & read word line drivers 35-2 and 34-2.

5 In the circuit shown in FIG. 1, the memory cells MC11 to MC18, MC21 to MC28, MC31 to MC38, and MC41 to MC48 corresponding to 32 bits are exemplified. In an actual MRAM, the memory cells are two-dimensionally appropriately integrated and laid out. In this example, 4-bit memory cells are connected to each of  
10 the sub bit lines SBL1 to SBL4. This structure can also be appropriately changed.

FIG. 2 is a timing chart of the read operation when the memory cell MC22 is selected. In the stand-by state, all the MOS transistors Q1 to Q8 serving as  
15 select switches between the sub bit lines SBL1 to SBL8 and the main bit lines MBL1 to MBL4 are set in the OFF state. Hence, the select lines SS1 and SS2 are in a low potential state. On the other hand, all the main bit lines MBL1 to MBL4 are set to a predetermined bias  
20 voltage by the bit line bias circuits 31-1 to 31-4. When the column select signals CSL1 to CSL 4 as the output signals from the column decoder & CSL driver 33 are set to a low potential, the sense amplifier 32 is disconnected from all the bit lines (main bit lines  
25 MBL1 to MBL4 and sub bit lines SBL1 to SBL8). All the word lines RWL1 to RWL8 are connected to the bias circuit (word line bias circuit) 36 by setting

the output signals RWLACT1 to RWLACT8 for the second  
row decoders & read word line drivers 34-1 and 34-2 to  
a low potential and the output signals RWLSET1 and  
RWLSET2 from the first row decoders & read word line  
5 drivers 35-1 and 35-2 to a high potential.

The word line bias circuit 36 and bit line bias  
circuits 31-1 to 31-4 generate almost the same bias  
voltage. In the stand-by state, all the main bit lines  
MBL1 to MBL4 and read word lines RWL1 to RWL8 are  
10 precharged to the same potential. In addition, since  
the MTJ elements MC11 to MC48 are mere resistive  
elements, all the sub bit lines SBL1 to SBL8 are set to  
the same potential as that of the word lines and bit  
lines through the read word lines RWL1 to RWL8.

15       Conversely, in the active state, since it is  
assumed that the memory cell MC22 is selected, the  
select line SS1 as the gate input signal and the word  
line drive signal RWLACT2 change to a high potential,  
and the word line potential setting signal RWLSET1  
20 changes to a low potential. Accordingly, a current  
path is formed through MBL2 → SBL3 → RWL2. In  
addition, the column select signal CSL2 changes to the  
high potential upon inputting the column address signal  
corresponding to the selected cell MC22, so the  
25 selected main bit line MBL2 and sense amplifier 32 are  
electrically connected. As a result, only data of  
the selected cell MC22 is transferred to the sense



amplifier 32, detected and amplified, and then read out from the memory through a read system circuit group (not shown). At this time, the bias circuit 31-2 of the selected main bit line MBL2 is set in the inactive state by the column select signal CSL2.

The word lines RWL1, RWL3, and RWL4 for the remaining unselected cells connected to the sub bit line SBL3 including the selected cell MC22 are controlled to the electrically floating state because the word line potential setting signal RWLSET1 changes to the low potential. At this time, the word line potential setting signal RWLSET2 still holds the high potential state. Hence, the word lines RWL5 to RWL8 of the memory cells MC15 to MC18, MC25 to MC28, MC35 to MC38, and MC45 to MC48 connected to the sub bit lines SBL2, SBL4, SBL6, and SBL8, which do not include the selected cell MC22, are kept connected to the word line bias circuit 36. As a result, the word lines RWL5 to RWL8 hold to be equipotential to the main bit lines MBL1 to MBL4. For this reason, the potentials of the sub bit lines SBL2, SBL4, SBL6, and SBL8 which are disconnected from the main bit lines MBL1 to MBL4 are also set in a low impedance state. Hence, the sub bit lines SBL2, SBL4, SBL6, and SBL8 can hold to be equipotential to the main bit lines MBL1 to MBL4. Accordingly, when an arbitrary memory cell connected to the sub bit lines SBL2, SBL4, SBL6, and SBL8 is

accessed in the next cycle, any variation or decrease in speed can be avoided.

[Second Embodiment]

FIG. 3 is a block diagram showing the schematic  
5 structure of an MRAM according to the second embodiment of the present invention. The same reference numerals as in FIG. 1 denote the same parts in FIG. 3, and a detailed description thereof will be omitted. The second embodiment is different from the first  
10 embodiment in that a row decoder & read word line driver is arranged only at one end of each of read word lines RWL1 to RWL8, though the row decoders & read word line drivers are arranged at two ends in FIG. 1.

To implement this circuit scheme, selection  
15 circuits 37-1 and 37-2 which selectively select the read word lines RWL1 to RWL4 and RWL5 to RWL8 to a bias circuit 36 for each cell unit are arranged. The selection circuit 37-1 is constituted by NMOS  
transistors Q41 to Q44 each of which has a current path  
20 having one end connected to a corresponding one of the read word lines RWL1 to RWL4 and the other end commonly connected to the output terminal of the bias circuit 36, and an inverter 38-1 which logically inverts a gate signal (a signal that is transferred through a select  
25 line SS1 to selectively connect sub bit lines SBL1, SBL3, SBL5, and SBL7 to main bit lines MBL1 to MBL4) output from a row decoder & read word line driver 34.

A signal bSS1 output from the inverter 38-1 is supplied to the gates of the MOS transistors Q41 to Q44.

The selection circuit 37-2 is constituted by NMOS transistors Q45 to Q48 each of which has a current path

5 having one end connected to a corresponding one of the read word lines RWL5 to RWL8 and the other end commonly connected to the output terminal of the bias circuit 36, and an inverter 38-2 which logically  
10 inverts a gate signal (a signal that is transferred through a select line SS2 to selectively connect sub bit lines SBL2, SBL4, SBL6, and SBL8 to the main bit lines MBL1 to MBL4) output from a row decoder & read word line driver 35. A signal bSS2 output from the inverter 38-2 is supplied to the gates of the MOS  
15 transistors Q45 to Q48.

FIG. 4 is an operation timing chart of the MRAM according to the second embodiment. As is apparent from the comparison between the timing chart shown in FIG. 4 and that shown in FIG. 2, the basic operation is  
20 the same as in the first embodiment except that the inverted signals bSS1 and bSS2 of the gate signals (select lines SS1 and SS2) are used for the operation of selectively connecting the read word lines RWL1 to RWL4 and RWL5 to RWL8 to the bias circuit 36 for each  
25 cell unit.

Hence, in the second embodiment as well, the same functions and effects as in the above-described first

embodiment can be obtained.

[Third Embodiment]

FIG. 5 is a block diagram showing the schematic structure of an MRAM according to the third embodiment of the present invention. In the third embodiment, a row decoder & read word line driver is arranged only at one end of each of read word lines RWL1 to RWL8, as in FIG. 3, though the row decoders & read word line drivers are arranged at two ends in FIG. 1. Selection circuits 39-1 and 39-2 are formed from PMOS transistors Q51 to Q54 and Q55 to Q58 to directly supply gate signals (signals that are transferred through select lines SS1 and SS2 to selectively connect sub bit lines to main bit lines) to the MOS transistors Q51 to Q54 and Q55 to Q58.

FIG. 6 is an operation timing chart in the third embodiment. The basic operation is the same as in the first and second embodiments except that the gate signals (the potentials of the select lines SS1 and SS2) are used for the operation of selectively connecting the read word lines RWL1 to RWL4 and RWL5 to RWL8 to the bias circuit 36 for each cell unit.

Hence, in the third embodiment as well, the same functions and effects as in the above-described first and second embodiments can be obtained.

As described above, according to the embodiments of the present invention, since cross-point memory

cells which require no cell selection elements are used, the capacity or the degree of integration can easily be increased. In addition, the divided bit line structure (hierarchical bit line scheme) is employed.

5 In the read operation, the word lines of all memory cells connected to the same sub bit line (divided bit line) as that of the selected memory cell are held in the electrically floating state. In addition, the same potential as that of all the main bit lines is supplied  
10 to the word lines of all memory cells connected to sub bit lines (divided bit lines) different from the selected cell. Accordingly, the error current component in the read mode, which is unique to the cross-point memory cells, can be suppressed.

15 Furthermore, when the potential of all the sub bit lines (divided bit lines) in the unselected state is set to the same potential as that of the main bit lines, the speed of read operation can be increased. Hence, an MRAM which can easily increase the capacity,  
20 has a large read operation margin, and is capable of high-speed read access can be implemented.

The magnetic random access memories (semiconductor memory devices) according to the first to third embodiments of the present invention can be applied to  
25 various apparatuses. FIGS. 7 to 13 shows application examples.

(Application Example 1)

FIG. 7 shows the DSL (Digital Subscriber Line) data path portion of a DSL modem. This modem includes a programmable digital signal processor (DSP) 100, analog/digital (A/D) converter 110, digital/analog (D/A) converter 120, a transmission driver 150, and receiver amplifier 160. FIG. 7 does not illustrate a bandpass filter. Instead, a magnetic random access memory 170 according to one of the embodiments and an EEPROM 180 are illustrated as optional memories of various types to hold a line code program (a program which is executed by the DSP to select and operate a modem in accordance with encoded subscriber line information and transmission conditions [line code; QAM, CAP, RSK, FM, AM, PAM, DWMT, and the like]).

In Application Example 1, two kinds of memories, i.e., the magnetic random access memory 170 and EEPROM 180 are used as memories to hold the line code program. The EEPROM 180 may be replaced with a magnetic random access memory. That is, instead of using two types of memories, only magnetic random access memories may be used.

(Application Example 2)

FIG. 8 shows a cellular telephone terminal 300 as another application example. A communication section 200 which implements a communication function comprises a transmitting/receiving antenna 201, an antenna

duplexer 202, a receiving section 203, a baseband  
processing section 204, a DSP 205 used as a voice  
codec, a loudspeaker (receiver) 206, a microphone  
(transmitter) 207, a transmitting section 208, and  
5 a frequency synthesizer 209.

The cellular telephone terminal 300 has a control  
section 220 which controls the sections of the cellular  
telephone terminal. The control section 220 is  
a microcomputer which is formed by connecting a CPU  
10 221, a ROM 222, a magnetic random access memory (MRAM)  
223 according to one of the embodiments, and a flash  
memory 224 through a CPU bus 225. The ROM 222 stores,  
in advance, a program to be executed by the CPU 221  
and data necessary for display fonts and the like.  
15 The MRAM 223 is mainly used as a word area where the  
CPU 221 stores data midway through calculation during  
executing the program as needed, or data exchanged  
between the control section 220 and the respective  
sections are temporarily stored. Even when the  
20 cellular telephone terminal 300 is powered off, the  
flash memory 224 stores, e.g., the immediately  
preceding set conditions, so the same set conditions  
can be used when the cellular telephone terminal 300 is  
powered on again. Accordingly, even when the cellular  
25 telephone terminal is powered off, the stored setting  
parameters are not erased.

The cellular telephone terminal 300 also has

an audio playback processing section 211, an external  
output terminal 212, an LCD controller 213, a LCD  
(liquid crystal display) 214 for display, and a ringer  
215 which generates a ringing signal. The audio  
5 playback processing section 211 plays back audio  
information input to the cellular telephone terminal  
300 (or audio information stored in an external memory  
240 (to be described later)). The audio information  
that is played back can be transmitted to an earphone  
10 or a portable loudspeaker through the external output  
terminal 212 and extracted to the outside. When the  
audio playback processing section 211 is arranged,  
audio information can be reproduced in this way.  
The LCD controller 213 receives display information  
15 from, e.g., the CPU 221 through the CPU bus 225,  
converts the display information into LCD control  
information to control the LCD 214, and drives the LCD  
214 to cause it to perform display.

The cellular telephone terminal 300 also has  
20 interface circuits (I/Fs) 231, 233, and 235, the  
external memory 240, an external memory slot 232, a key  
operation section 234, and an external input/output  
terminal 236. The external memory slot 232 receives  
the external memory 240 such as a memory card.  
25 The external memory slot 232 is connected to the CPU  
bus 225 through the interface circuit (I/F) 231.  
As described above, when the slot 232 is prepared in



the cellular telephone terminal 300, information in the cellular telephone terminal 300 can be written in the external memory 240. Alternatively, information (e.g., audio information) stored in the external memory 240  
5 can be input to the cellular telephone terminal 300. The key operation section 234 is connected to the CPU bus 225 through the interface circuit (I/F) 233. Key input information input from the key operation section 234 is transmitted to, e.g., the CPU 221. The external  
10 input/output terminal 236 is connected to the CPU bus 225 through the interface circuit (I/F) 233 and functions as a terminal in inputting various kinds of external information to the cellular telephone terminal 300 or outputting information externally from the  
15 cellular telephone terminal 300.

In Application Example 2, the ROM 222, MRAM 223, and flash memory 224 are used. The flash memory 224 may be replaced with a magnetic random access memory. The ROM 222 may also be replaced with a magnetic random  
20 access memory.

(Application Example 3)

FIGS. 9 to 13 show an example in which a magnetic random access memory is applied to a card (MRAM card) such as a smart medium which stores  
25 media contents.

An MRAM card main body 400 incorporates an MRAM chip 401. An opening portion 402 is formed in the card

main body 400 at a position corresponding to the MRAM chip 401 so the MRAM chip 401 is exposed. The opening portion 402 has a shutter 403. When the MRAM card is carried, the MRAM chip 401 is protected by the shutter 403. The shutter 403 is made of a material such as a ceramic capable of shielding an externally magnetic field. When data is to be transferred, the shutter 403 is opened to expose the MRAM chip 401. An external terminal 404 is used to extract content data stored in the MRAM card.

FIGS. 10 and 11 show a transfer apparatus which transfers data to the MRAM card. FIG. 10 is a plan view of a card insertion type transfer apparatus. FIG. 11 is a sectional view of the transfer apparatus. A second MRAM card 450 used by an end user is inserted from an insertion portion 510 of a transfer apparatus 500, as indicated by the arrow, and pushed into until the card abuts against a stopper 520. The stopper 520 also functions as a member to position a first MRAM 550 and the second MRAM card 450. When the second MRAM card 450 is located at a predetermined position, a control signal is supplied from a first MRAM rewrite control section to an external terminal 530 to transfer data stored in the first MRAM 550 to the second MRAM card 450.

FIG. 12 shows a fitting type transfer apparatus. In this transfer apparatus, the second MRAM card 450 is

fitted on the first MRAM 550 with reference to the stopper 520, as indicated by the arrow. The transfer method is the same as in the card insertion type, and a description thereof will be omitted.

5           FIG. 13 shows a slide type transfer apparatus. The transfer apparatus 500 has a sliding tray 560, like a CD-ROM drive or DVD drive. The sliding tray 560 moves, as indicated by the arrow. When the sliding tray 560 moves to the position indicated by the broken  
10           line, the second MRAM card 450 is mounted on the sliding tray 560 and conveyed into the transfer apparatus 500. The structure that conveys the second MRAM card 450 until it abuts against the stopper 520 and the transfer method are the same as in the card  
15           insertion type, and a description thereof will be omitted.

          As described above, according to one aspect of this invention, a magnetic random access memory which can increase the capacity or the degree of integration  
20           and also realize a high access speed, and a data read method thereof can be obtained.

          Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to  
25           the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the

spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.